

9 automatically, under computer program control, revising the initial computer program
10 to generate a revised computer program by adding object loading instructions to the initial
11 computer program at the first set of the identified program locations, wherein the added
12 object loading instructions, during execution of the revised computer program, load
13 respective ones of the objects from persistent storage of the computer into the main memory
14 when each respective object is accessed and the respective object is not already in the main
15 memory.

16 23. The method of claim 22, wherein the added object loading instructions are inactive
17 during execution of the revised computer program except when a respective object to be
18 accessed is referenced by a null location indicator.

1 24. The method of claim 22,
2 the revising further includes:

3 adding dirty object marking instructions to the initial computer program that,
4 during execution of the revised computer program, store object marking data indicating
5 which objects in the main memory contain new and/or updated data; and

6 adding object storing instructions to the initial computer program that, during
7 execution of the revised computer program, store certain respective objects in the main
8 memory into the persistent storage;

9 wherein the certain respective objects stored into the persistent storage by the object
10 storing instructions contain new and/or updated data as indicated by the object marking data.

1 25. The method of claim 24, wherein the object storing instructions include instructions
2 for replacing main memory object references in the certain respective objects with
3 corresponding persistent storage object identifiers before storing the certain respective objects
4 in the persistent storage.

1 26. A method of generating object-oriented computer programs for accessing and
2 updating persistently stored objects, wherein the method is performed under program control
3 by a computer, the method comprising:

receiving an initial computer program that includes original instructions for accessing and updating objects stored in a computer's main memory and for committing transactions in which one or more objects may have been updated;

scanning the initial computer program to automatically identify object updating instructions and transaction commit instructions and corresponding program locations at which additional instructions are to be added representing a set of identified program locations;

automatically, under computer program control, revising the initial computer program to generate a revised computer program by:

adding at a first subset of the identified program locations dirty object marking instructions to the initial computer program that, during execution of the revised computer program, store object marking data indicating which objects in the computer's main memory contain new and/or updated data; and

adding at a second subset of the identified program locations object storing instructions to the initial computer program that, during execution of the revised computer program, store certain respective objects in the computer's main memory into the persistent storage, wherein the object marking data stored by the dirty object marking instructions is used by the object storing instructions to identify the certain respective objects.

27. The method of claim 26, wherein the object storing instructions include instructions for replacing local object references in the certain respective objects with corresponding persistent storage object identifiers before storing the certain respective objects in the persistent storage, wherein the local object references reference objects in the main memory and the persistent storage object identifiers reference objects in the persistent storage.

28. A method of generating object-oriented computer programs for accessing and updating persistently stored objects, wherein the method is performed under program control by a computer, the method comprising:

scanning an initial computer program to automatically identify object accessing instructions and object updating instructions and corresponding program locations at which additional instructions are to be added;

8 automatically revising the initial computer program to generate a revised computer
9 program by adding supplemental instructions to the initial computer program at the identified
10 program locations, the supplemental instructions including:

11 a first set of additional instructions, added to the initial computer program at a
12 first subset of the identified program locations associated with identified object accessing
13 instructions, wherein the first set of additional instructions, during execution of the revised
14 computer program, perform a first predefined task when each respective object is accessed
15 and the respective object is not already in main memory of the computer; and

16 a second set of additional instructions, added to the initial computer program
17 at a second subset of the identified program locations associated with the identified object
18 updating instructions, wherein the second set of additional instructions, during execution of
19 the revised computer program, perform a second predefined task when each respective object
is updated for a first time.

1 29. The computer implemented method of claim 28, wherein the first predefined task
2 includes loading respective ones of the objects from persistent storage of the computer into
3 the main memory of the computer when each respective object is accessed and the respective
4 object is not already in the main memory.

1 30. The computer implemented method of claim 29, wherein the second predefined task
2 includes storing object marking data indicating which objects in the main memory contain
3 new and/or updated data.

1 31. The computer implemented method of claim 29, wherein
2 the scanning includes scanning the initial computer program to automatically identify
3 transaction commit instructions and corresponding program locations at which further
4 additional instructions are to be added to the initial computer program;
5 the revising includes adding at a third subset of the identified program locations
6 object storing instructions to the initial computer program that, during execution of the
7 revised computer program, store certain respective objects in the computer's main memory
8 into the persistent storage, wherein the object marking data stored by the dirty object marking
9 instructions is used by the object storing instructions to identify the certain respective objects.

32. A computer program product for use in conjunction with a computer having a main memory and persistent storage, the computer program product comprising a computer readable storage medium and a computer program mechanism embedded therein, the computer program mechanism comprising:

- a postprocessor procedure for modifying an initial computer program that includes original instructions for accessing and updating objects stored in a computer's main memory;
- the postprocessor procedure including instructions for:
 - receiving an initial computer program that includes original instructions for accessing objects stored in a computer's main memory;
 - scanning the initial computer program to automatically identify object accessing instructions and corresponding program locations at which additional instructions are to be added representing a first set of identified program locations;
 - automatically, under computer program control, revising the initial computer program to generate a revised computer program by adding object loading instructions to the initial computer program at the first set of the identified program locations, wherein the added object loading instructions, during execution of the revised computer program, load respective ones of the objects from persistent storage of the computer into the main memory when each respective object is accessed and the respective object is not already in the main memory.

33. The computer program product of claim 32, wherein the added object loading instructions are inactive during execution of the revised computer program except when a respective object to be accessed is referenced by a null location indicator.

34. The computer program product of claim 32, wherein the revising instructions further include instructions for:

- adding dirty object marking instructions to the initial computer program that, during execution of the revised computer program, store object marking data indicating which objects in the main memory contain new and/or updated data; and

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adding object storing instructions to the initial computer program that, during execution of the revised computer program, store certain respective objects in the main memory into the persistent storage;
wherein the certain respective objects stored into the persistent storage by the object storing instructions contain new and/or updated data as indicated by the object marking data.

35. The computer program product of claim 34, wherein the object storing instructions include instructions for replacing main memory object references in the certain respective objects with corresponding persistent storage object identifiers before storing the certain respective objects in the persistent storage.

36. A computer program product for use in conjunction with a computer having a main memory and persistent storage, the computer program product comprising a computer readable storage medium and a computer program mechanism embedded therein, the computer program mechanism comprising:
a postprocessor procedure for modifying an initial computer program that includes original instructions for accessing and updating objects stored in a computer's main memory;
the postprocessor procedure including instructions for:
receiving an initial computer program that includes original instructions for accessing and updating objects stored in a computer's main memory and for committing transactions in which one or more objects may have been updated;
scanning the initial computer program to automatically identify object updating instructions and transaction commit instructions and corresponding program locations at which additional instructions are to be added representing a set of identified program locations;
automatically, under computer program control, revising the initial computer program to generate a revised computer program by:
adding at a first subset of the identified program locations dirty object marking instructions to the initial computer program that, during execution of the revised computer program, store object marking data indicating which objects in the computer's main memory contain new and/or updated data; and

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21 adding at a second subset of the identified program locations object storing
22 instructions to the initial computer program that, during execution of the revised computer
23 program, store certain respective objects in the computer's main memory into the persistent
24 storage, wherein the object marking data stored by the dirty object marking instructions is
25 used by the object storing instructions to identify the certain respective objects.

1 37. The computer program product of claim 36, wherein the object storing instructions
2 include instructions for replacing local object references in the certain respective objects with
3 corresponding persistent storage object identifiers before storing the certain respective objects
4 in the persistent storage, wherein the local object references reference objects in the main
5 memory and the persistent storage object identifiers reference objects in the persistent
6 storage.

1 38. A computer program product for use in conjunction with a computer having a main
2 memory and persistent storage, the computer program product comprising a computer
3 readable storage medium and a computer program mechanism embedded therein, the
4 computer program mechanism comprising:

5 a postprocessor procedure for modifying an initial computer program that includes
6 original instructions for accessing and updating objects stored in a computer's main memory;

7 the postprocessor procedure including instructions for:

8 scanning an initial computer program to automatically identify object accessing
9 instructions and object updating instructions and corresponding program locations at which
10 additional instructions are to be added;

11 automatically revising the initial computer program to generate a revised computer
12 program by adding supplemental instructions to the initial computer program at the identified
13 program locations, the supplemental instructions including:

14 a first set of additional instructions, added to the initial computer program at a
15 first subset of the identified program locations associated with identified object accessing
16 instructions, wherein the first set of additional instructions, during execution of the revised
17 computer program, perform a first predefined task when each respective object is accessed
18 and the respective object is not already in main memory of the computer; and

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19 *Supp* a second set of additional instructions, added to the initial computer program
20 at a second subset of the identified program locations associated with the identified object
21 updating instructions, wherein the second set of additional instructions, during execution of
22 the revised computer program, perform a second predefined task when each respective object
23 is updated for a first time.

1 39. The computer program product of claim 38, wherein the first predefined task includes
2 loading respective ones of the objects from persistent storage of the computer into the main
3 memory of the computer when each respective object is accessed and the respective object is
4 not already in the main memory.

1 40. The computer program product of claim 39, wherein the second predefined task
2 includes storing object marking data indicating which objects in the main memory contain
3 new and/or updated data.

1 41. The computer program product of claim 39, wherein
2 the scanning instructions include instructions for scanning the initial computer
3 program to automatically identify transaction commit instructions and corresponding
4 program locations at which further additional instructions are to be added to the initial
5 computer program;
6 the revising instructions include instructions for adding at a third subset of the
7 identified program locations object storing instructions to the initial computer program that,
8 during execution of the revised computer program, store certain respective objects in the
9 computer's main memory into the persistent storage, wherein the object marking data stored
10 by the dirty object marking instructions is used by the object storing instructions to identify
11 the certain respective objects.

1 42. A computer system, comprising:
2 a central processing unit;
3 memory, including a main memory for temporarily storing objects and persistent
4 storage for durably storing objects;

45. The computer system of claim 44, wherein the object storing instructions include instructions for replacing main memory object references in the certain respective objects with corresponding persistent storage object identifiers before storing the certain respective objects in the persistent storage.

46. A computer system, comprising:
a central processing unit;
memory, including a main memory for temporarily storing objects and persistent storage for durably storing objects;
the memory further storing an initial computer program and a postprocessor procedure, executable by the central processing unit, for modifying an initial computer program so as to generate the revised computer program, the initial computer program including original instructions for accessing objects stored in the main memory;
the postprocessor procedure including instructions for:
receiving an initial computer program that includes original instructions for accessing and updating objects stored in a computer's main memory and for committing transactions in which one or more objects may have been updated;
scanning the initial computer program to automatically identify object updating instructions and transaction commit instructions and corresponding program locations at which additional instructions are to be added representing a set of identified program locations;
automatically, under computer program control, revising the initial computer program to generate a revised computer program by:
adding at a first subset of the identified program locations dirty object marking instructions to the initial computer program that, during execution of the revised computer program, store object marking data indicating which objects in the computer's main memory contain new and/or updated data; and
adding at a second subset of the identified program locations object storing instructions to the initial computer program that, during execution of the revised computer program, store certain respective objects in the computer's main memory into the persistent

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storage, wherein the object marking data stored by the dirty object marking instructions is used by the object storing instructions to identify the certain respective objects.

1 47. The computer system of claim 46, wherein the object storing instructions include
2 instructions for replacing local object references in the certain respective objects with
3 corresponding persistent storage object identifiers before storing the certain respective objects
4 in the persistent storage, wherein the local object references reference objects in the main
5 memory and the persistent storage object identifiers reference objects in the persistent
6 storage.

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23 updating instructions, wherein the second set of additional instructions, during execution of
24 the revised computer program, perform a second predefined task when each respective object
25 is updated for a first time.

1 49. The computer system of claim 48, wherein the first predefined task includes loading
2 respective ones of the objects from persistent storage of the computer into the main memory
3 of the computer when each respective object is accessed and the respective object is not
4 already in the main memory.

1 50. The computer system of claim 49, wherein the second predefined task includes storing
2 object marking data indicating which objects in the main memory contain new and/or
3 updated data.

1 51. The computer system of claim 49, wherein
2 the scanning instructions include instructions for scanning the initial computer
3 program to automatically identify transaction commit instructions and corresponding
4 program locations at which further additional instructions are to be added to the initial
5 computer program;
6 the revising instructions include instructions for adding at a third subset of the
7 identified program locations object storing instructions to the initial computer program that,
8 during execution of the revised computer program, store certain respective objects in the
9 computer's main memory into the persistent storage, wherein the object marking data stored
10 by the dirty object marking instructions is used by the object storing instructions to identify
11 the certain respective objects.